Volume 8 JUNE 2, 1933 Number 4

BULLETIN

OF THE

AMERICAN PHYSICAL SOCIETY

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PROGRAM

FOR THE

CHICAGO MEETING

JUNE 19–24, 1933

JOINT MEETING

—WITH—

SECTION B—PHYSICS—of

The American Association for the Advancement of Science
In Connection with A Century of Progress Exposition.

PUBLISHED BY THE AMERICAN PHYSICAL SOCIETY
SEVEN ISSUES EACH YEAR

The American Physical Society

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BULLETIN

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JUNE 2, 1933 Vol. 8, Number 4

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OF THE

AMERICAN PHYSICAL SOCIETY

CHICAGO MEETING, JUNE 19–24, 1933

JOINT MEETING WITH SECTION B—PHYSICS—of

THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE IN CONNECTION WITH A CENTURY OF PROGRESS EXPOSITION.

THE 186th regular meeting of the American Physical Society will be held in Chicago, Illinois, June 19–24, 1933, as a joint meeting with Section B of the American Association for the Advancement of Science.

A Century of Progress Exposition. At the dedication of the Hall of Science President Dawes said: "We desire to present as a central theme of our Exposition, the progress of civilization during the one hundred years of Chicago's existence. This seems to us especially appropriate because this period represents also the great period of development of the physical sciences and their application to the services of man. We feel that a new value can be given to the enterprise by making its central idea an exposition of the service of science to society, and of the benefit to humanity brought about by this scientific and industrial development."

The various sections of Basic Science, Mathematics, Physics, Chemistry, Biology, Geology, Astronomy and Medical Science are represented by exhibits that are striking. They are true and fundamental but not too complex to be readily grasped. The exhibit as a whole is a strong demonstration of the Unity of Science.

Dinner. On Wednesday evening at six-fifteen o'clock there will be a dinner for the members of the American Physical Society and their friends at the Congress Hotel.

American Institute of Physics Incorporated. The Chemical Foundation will have space near the entrance to the Science Hall of the Chicago Fair. The American Institute of Physics Incorporated will be represented here and may be called upon for information during the program of the Physical Society.

Sigma Pi Sigma. A luncheon for members and invited guests of Sigma Pi Sigma, honorary physics society, will be held on Tuesday, June 20th at twelve-thirty. The place will be announced on posters at the Physical Society sessions. Members expecting to attend the luncheon are requested to make reservations at the registration desk.

General Information

For further information in regard to sessions, meetings, receptions, exhibitions, excursions, etc., see the General Program of the A.A.A.S. which will be available at the registration offices. See also the Preliminary Announcement of the A.A.A.S. printed in current issues of Science.

Headquarters. The Hotels Windermere, 1600 East 56th Street, Hyde Park Station, have been selected for hotel headquarters for the American Physical Society. Members are urged to make their reservations at once (writing directly to the hotel).

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The rates at the Windermere are: single rooms, $3.50 per day; double rooms, $6.00 per day.

Other hotels in the neighborhood are: the Shoreland, just north of the Windermere, offers a $6.00 double rate only; the Aragon Hotel, 5401 Cornell Avenue, $2.50 single, $4.00 double; the Broadview Hotel, 5540 Hyde Park Boulevard, $2.50 single, $3.50 double; the Southmoor, 6610 Stoney Island Avenue, $2.50 single (bus connection to University); the Gladstone, 6200 Kenwood, $1.50 up single, $2.00 up double.

For rates at many other hotels see current issues of Science.

Railroad Rates. Any person attending the meetings of the A.A.A.S. or its Affiliated Societies, may take advantage of the reduced railroad rates, on the usual certificate plan. Certificate must be obtained from ticket agent at starting point (or nearest station issuing through tickets to place of meeting) and in order to be valid for the reduced fare returning, it must be endorsed by Mr. Sam Woodley, Executive Assistant, American Association for the Advancement of Science, indicating that the holder is a member of your organization (or of one of the various Associations), has been in attendance at the meeting, or is a dependent member of his or her family, and is entitled to the reduction. In addition, the certificate must be validated by the Special Agent of the carriers upon the date or dates arranged for this purpose. As persons arrive at the meeting, their certificates should be collected, so as to expedite the validation of the certificates on the arrival of the Special Agent.

Some railroads may offer excursions at lower rates than the Certificate Plan. *In any case members should consult with their local passenger agents before purchasing their tickets.*

General Rules Relating to Papers

Only those titles of papers shall be listed on the preliminary program of a meeting of the Society for which abstracts ready for publication are in the hands of the Secretary.

When two or more papers are offered by the same member, one only of these will be assigned a place on the regular program, while the others will be placed in a supplementary program. In the case of a paper with joint authors the paper will be assigned to the author whose name appears first.

Papers received after the program has been printed will be placed in the supplementary program. The presiding officer may in his discretion call for such papers to be read by title only.

Except by special vote of the Society, the maximum allowance of time for the presentation of a paper shall be ten minutes. The presiding officer shall enforce this rule.

The supplementary papers may be called for at the end of the regular sessions in Eckhart Hall, Room 202.

Titles and abstracts of the papers to be presented before the Society are given in the following pages. These abstracts have not been corrected by the authors. After correction they will be published in an early issue of the Physical Review. Authors should send corrections to the Editorial Secretary, American Institute of Physics Incorporated, 11 East 38th Street, New York, New York.

Other meetings for the current season are as follows:

187. Cincinnati. December 1–2, 1933.

188. December 1933. Pacific Coast. Time and place to be announced later.

189. December 28–30, 1933. Annual Meeting. Boston.

W. L. Severinghaus, *Secretary*
Columbia University, New York, N. Y.

June 2, 1933.

CALENDAR

Monday Morning

9:30 o'clock: Eckhart Hall: Rooms 133 and 202. Ryerson Laboratory: Room 32. Contributed Papers. See pages 12–18.

Monday Afternoon

2:00 o'clock: Eckhart Hall: Room 202. Ryerson Laboratory: Rooms 32 and 33. Contributed Papers. See pages 19–26.

2:00 o'clock: Rosenwald Hall, Room 2: Meteorology Symposium. See page 6.

Monday Evening

Hall of Science, Fair Grounds: A.A.A.S. Reception.

Tuesday Morning

9:30 o'clock: International House: Auditorium: Sections B and C: Symposium. See page 6.

9:30 o'clock: Mandel Hall: Meteorology Papers. See page 7.

Tuesday Afternoon

1:30 o'clock: Eckhart Hall, Room 133: Meteorology Papers. See page 7.

1:45 o'clock: Mandel Hall: Section A (Mathematics). See page 7.

4:30 o'clock: Fair Grounds: Public Address by J. Bjerknes. See page 8.

Tuesday Evening

6:30 o'clock: Judson Court: Section E (Geology and Geography). Dinner.

Wednesday Morning

9:30 o'clock: International House: Sections B and C: Symposium. See page 8.

9:30 o'clock: Mandel Hall: Mathematics Symposium. See page 8.

9:30 o'clock: Eckhart Hall, Room 133: Meteorology Symposium. See page 9.

Wednesday Afternoon

2:00 o'clock: South Hall, Hall of Science, Fair Grounds: Sections B, C and E: Symposium. See page 9.

4:30 o'clock: Fair Grounds: Italian Building: Public Address by Enrico Fermi. See page 9.

Wednesday Evening

6:15 o'clock: Congress Hotel: Physical Society Dinner.

8:00 o'clock: Addresses by F. W. Aston and R. A. Millikan. See page 10.

Thursday Morning

9:30 o'clock: International House: Astronomy Symposium. See page 10.

Thursday Afternoon

4:30 o'clock: Fair Grounds, Italian Building: Public Address by Niels Bohr. See page 10.

Thursday Evening

7:00 o'clock: Stevens Hotel: A.A.A.S. Dinner.

Friday Morning

9:30 o'clock: International House: Symposium. See page 11.

Friday Evening

Judson Court: Section A Dinner.
Midland Club: Section C Dinner.

8:00 o'clock: Field Museum. Open House to A.A.A.S.

9:00 o'clock: Address by C. A. Kappers.

Saturday Morning

9:30 o'clock: Mandel Hall: International Union of Pure and Applied Physics. See page 11.

PROGRAM

MONDAY MORNING SESSION, JUNE 19, 9:30 A.M.

Eckhart Hall, Rooms 133 and 202
Ryerson Physical Laboratory, Room 32

Sessions for reading contributed papers of the American Physical Society. Abstracts on pages 12–18

MONDAY AFTERNOON SESSION, JUNE 19, 2:00 P.M.

Eckhart Hall, Room 202
Ryerson Physical Laboratory, Rooms 32 and 33

Sessions for reading contributed papers of the American Physical Society. Abstracts on pages 19–26

MONDAY AFTERNOON SESSION, JUNE 19, 2:00 P.M.

Rosenwald Hall, Room 2

American Meteorological Society

SYMPOSIUM

"DYNAMICS OF EXTRATROPICAL CYCLONES."

1. Vertical Cross-Sections through Extratropical Cyclones. (30 min.) J. BJERKNES, *Geophysical Institute, Bergen, Norway.*

2. The Cyclone of November 18–19, 1931. ANDREW THOMSON, *Meteorological Office, Toronto, Canada.*

3. C. G. ROSSBY, *Massachusetts Institute of Technology.*

4. Origins of Extratropical Cyclones. W. J. HUMPHREYS, *U. S. Weather Bureau, Washington, D. C.*

5. Concerning Vertical Currents in the Atmosphere. (30 min.) K. O. LANGE, *Massachusetts Institute of Technology.*

MONDAY EVENING SESSION, JUNE 19

Hall of Science, Fair Grounds

A.A.A.S. Reception

TUESDAY MORNING SESSION, JUNE 20, 9:30 A.M.

International House, Auditorium

Joint Session, American Physical Society, Section B and Section C

SYMPOSIUM

"APPLICATION OF QUANTUM MECHANICS IN CHEMISTRY."

1. Electron Energies in Atoms and Molecules. (25 min.) J. C. SLATER, *Massachusetts Institute of Technology.*

2. Quantum Mechanics of Condensed Ring Systems, Free Radicals and Other Complex Molecules. (25 min.) LINUS PAULING, *California Institute of Technology.*

3. **Quantum Mechanics and Chemical Reactions.** (25 min.) HENRY EYRING, *Princeton University.*

4. **Electronic Structures of Polyatomic Molecules.** (25 min.) R. S. MULLIKEN, *University of Chicago.*

TUESDAY MORNING SESSION, JUNE 20, 9:30 A.M.

Mandel Hall

American Meteorological Society

Miscellaneous Papers

1. **Pioneers in American Meteorology and the Founding of Weather Services.** (30 min.) ERIC R. MILLER, *U. S. Weather Bureau, Madison, Wis.*

2. **The Early History of Aerology in the U. S.** (20 min.) S. P. FERGUSSON, *Blue Hill Observatory, Harvard University.*

3. **History of the Application of Meteorology to Aeronautics with Special Reference to the U. S.** (25 min.) W. R. GREGG, *U. S. Weather Bureau, Washington, D. C.*

4. **On the Dynamics of Penetrative Convection.** (30 min.) J. BJERKNES, *Geophysical Institute, Bergen, Norway.*

5. **Periodicities in Rainfall.** (20 min.) DINSMORE ALTER, *University of Kansas.*

6. **Tornadoes.** (10 min.) TRUMAN G. SHIPMAN, *U. S. Weather Bureau, Davenport, Iowa.*

7. **Some Useful Temperature Relations.** (10 min.) R. A. DYKE, *U. S. Weather Bureau, New Orleans, La.*

TUESDAY AFTERNOON SESSION, JUNE 20, 1:30 P.M.

Eckhart Hall, Room 133

American Meteorological Society

Miscellaneous Papers

1. **The Use of Glass Color Screens in the Study of Atmospheric Depletion of Solar Radiation.** (15 min.) H. H. KIMBALL AND I. F. HAND, *Harvard University and U. S. Weather Bureau, Washington, D. C.*

2a. **Concerning Atmospheric Turbidity.** BERNHARD HAURWITZ, *Massachusetts Institute of Technology and Blue Hill Observatory, Harvard University.*

2b. **Remarks Concerning an Extension of the Angstrom Coefficient of Atmospheric Turbidity.** HARRY WEXLER, *Massachusetts Institute of Technology and Blue Hill Observatory, Harvard University.*

3. **Anemometer Experiments.** S. P. FERGUSSON, *Blue Hill Observatory, Harvard University.*

4. **Dynamic Climatology from the Massachusetts Institute of Technology Weather Maps.** (15 min.) PHIL E. CHURCH, *Moosehart, Ill.*

5. **A Proposal for Local Regional Studies of Flying Weather.** J. E. WOODMAN, *New York University.*

TUESDAY AFTERNOON SESSION, JUNE 20, 1:45 P.M.

Mandel Hall

Section A (Mathematics) with
Section B as guests

1. **Some Mathematical Aspects of the New Mechanics.** TULLIO LEVI-CIVITA, *University of Rome.*

2. **Quantum Mechanics and Asymptotic Series.** G. D. BIRKHOFF, *Harvard University.*

TUESDAY AFTERNOON SESSION, JUNE 20, 4:30 P.M.

Fair Grounds

PUBLIC ADDRESS

"ATMOSPHERIC SOUNDINGS: METHODS AND RESULTS." (45 min.) J. BJERKNES, *Geophysical Institute, Bergen, Norway.*

TUESDAY EVENING, JUNE 20, 6:30 P.M.

Judson Court

Section E (Geology and Geography)

Informal Dinner.

WEDNESDAY MORNING SESSION, JUNE 21, 9:30 A.M.

International House

Joint Session of Section C (Chemistry) with
Section B and the American Physical Society

SYMPOSIUM

"ISOTOPES."

1. Neutrons and Isotopes. (20 min.) W. D. HARKINS, *University of Chicago.*

2. Some Measurements of the Relative Abundance of Isotopes. (30 min.) F. W. ASTON, *University of Cambridge, England.*

3. Mass of Isotopes and Disintegration of Atoms. (30 min.) K. T. BAINBRIDGE, *Bartol Research Foundation.*

4. Isotopic Fractionation of Water. (10 min.) E. W. WASHBURN, *Bureau of Standards.*

5. Diffusion Method of Separation of Isotopes. (10 min.) HAROLD C. UREY, *Columbia University.*

6. The Magneto-Optic Method in the Study of Isotopes. (10 min.) FRED ALLISON, *Alabama Polytechnic Institute.*

WEDNESDAY MORNING SESSION, JUNE 21, 9:30 A.M.

Mandel Hall

American Mathematical Society and Section A

SYMPOSIUM

1. The Infinite Sequences Arising in the Theories of Harmonic Analysis, of Interpolation and of Mechanical Quadratures. LIPÓT FEJÉR, *University of Budapest.*

2. On the Use of Cesaro Means in Determining Criteria for Fourier's Constants. C. N. MOORE, *University of Cincinnati.*

WEDNESDAY MORNING SESSION, JUNE 21, 9:30 A.M.

Eckhart Hall, Room 133

American Meteorological Society

SYMPOSIUM

"RADIATION AND THE GENERAL CIRCULATION OF THE ATMOSPHERE."

1. **Solar Radiation as a Factor in Atmospheric Circulation.** (20 min.) H. H. KIMBALL, *Blue Hill Observatory, Harvard University.*

2. **Incoming and Outgoing Radiation as Affected by the Atmosphere.** W. J. HUMPHREYS, *U. S. Weather Bureau, Washington, D. C.*

3. **Radiation and General Circulation in Middle and High Latitudes in America.** (20 min.) JOHN PATTERSON, *Meteorological Office, Toronto, Canada.*

4. **A Theory of the General Circulation of the Atmosphere.** (30 min.) J. BJERKNES, *Geophysical Institute, Bergen, Norway.*

5. **Weather Types and Pressure Anomalies.** (20 min.) T. A. BLAIR, *U. S. Weather Bureau, Lincoln, Nebr.*

WEDNESDAY AFTERNOON SESSION, JUNE 21, 2:00 P.M.

South Hall, Hall of Science, Fair Grounds

Joint Session of Section E (Geology)
with Sections B and C and the American Physical Society.

SYMPOSIUM

"THE MEASUREMENT OF GEOLOGIC TIME."

1. **General Survey of the Problem.** (15 min.) ALFRED C. LANE, *Tufts College, Medford, Mass.*

2. **Working Formulae for the Age of a Radioactive Mineral.** (20 min.) A. F. KOVARIK, *Yale University.*

3. **The Significance of the Isotopes of Uranium and Lead.** (25 min.) C. S. PIGGOTT, *Geophysical Laboratory, Washington, D. C.*

4. **The Actinium Series of Radioactive Elements and the Measurement of Geologic Time.** (25 min.) A. v. GROSSE, *University of Chicago.*

5. **The "Helium Method." A New Outlook.** (25 min.) W. D. URRY, *Massachusetts Institute of Technology.*

6. **Thorianite from Eastern Pennsylvania.** (15 min.) R. C. WELLS, *Geological Survey, Washington, D. C.*

7. **Post-glacial Time Calculations from Recent Geothermal Gradient Measurements in the Calumet Copper Mines.** (15 min.) W. O. HOTCHKISS AND L. R. INGERSOLL, *Michigan College of Mines and Technology and University of Wisconsin.*

8. **The Radium Content of the Travertine Deposits of Mammoth Hot Springs, Yellowstone Park, as an Index of their Age.** (20 min.) HERMAN SCHLUNDT, *University of Missouri.*

WEDNESDAY AFTERNOON SESSION, JUNE 21, 4:30 P.M.

Fair Grounds, Italian Building

PUBLIC ADDRESS

"THEORY OF HYPERFINE STRUCTURES."

ENRICO FERMI, *University of Rome.*

WEDNESDAY EVENING, JUNE 21, 6:15 P.M.

Congress Hotel

American Physical Society Dinner.

WEDNESDAY EVENING SESSION, JUNE 21, 8:00 P.M.

Auditorium to be announced later.

Public Program Under the Auspices of
Sections B and C of the A.A.A.S.

1. **The Story of Isotopes.** (40 min.) F. W. ASTON, *University of Cambridge, England.*
2. **New Light on Nuclear Physics.** (40 min.) R. A. MILLIKAN, *California Institute of Technology.*

THURSDAY MORNING SESSION, JUNE 22, 9:30 A.M.

International House

Joint Session with the American Astronomical Society.

SYMPOSIUM

"SPECTROSCOPY AND ASTRONOMY."

1. **Technique of Stellar Spectrophotometry and Intensities of Some Stellar Absorption Lines.** (30 min.) THEODORE DUNHAM JR., *Mount Wilson Observatory.*
2. **Atomic Configuration in Spectroscopy.** (30 min.) A. G. SHENSTONE, *Princeton University.*
3. **Astrophysics and the Ionization Theory.** (30 min.) W. S. ADAMS, *Mount Wilson Observatory.*
4. **Matter in Inter-stellar Space.** (30 min.) OTTO STRUVE, *Yerkes Observatory.*

THURSDAY AFTERNOON SESSION, JUNE 22, 4:30 P.M.

Fair Grounds, Italian Building

PUBLIC ADDRESS

"SPACE AND TIME IN CONTEMPORARY PHYSICS."

NIELS BOHR, *University of Copenhagen.*

THURSDAY EVENING, JUNE 22, 7:00 P.M.

Stevens Hotel

Dinner for the American Association
for the Advancement of Science.

FRIDAY MORNING SESSION, JUNE 23, 9:30 A.M.

International House

SYMPOSIUM

"NUCLEAR DISINTEGRATION."

1. **Recent Work on Nuclear Disintegration at The University of California.** (15 min.) E. O. LAWRENCE, *University of California.*
2. **The Disintegration of Light Elements by High Velocity Protons.** (20 min.) J. D. COCKROFT, *University of Cambridge, England.*
3. **Disintegration Experiments on Elements of Medium Atomic Number.** (20 min.) M. A. TUVE, *Department of Terrestrial Magnetism, Washington, D. C.*
4. **Disintegration of Nuclei by Neutrons.** (15 min.) W. D. HARKINS, *University of Chicago.*

FRIDAY EVENING, JUNE 23

Dinner of Section A (Mathematics)—Judson Court
Dinner of Section C (Chemistry)—6:15 p.m., Midland Club

OPEN HOUSE TO THE A.A.A.S. AT THE FIELD MUSEUM, 8:00 P.M.

ADDRESS BY C. A. KAPPERS, *Brain Institute, Amsterdam*, 9:00 P.M.

SATURDAY MORNING SESSION, JUNE 24, 9:30 A.M.

Mandel Hall

American Section of the International Union
of Pure and Applied Physics with Foreign Guests.

R. A. MILLIKAN, *Chairman of International Union of Pure and Applied Physics.*
F. K. RICHTMYER, *Chairman of American Section of International Union of Pure and Applied Physics.*

PROGRAM

1. **The Broader Aspects of the International S.U.N. Committee's Activities.** SIR RICHARD GLAZEBROOK, *Chairman of the International S.U.N. Committee.*
2. **Magnetic Units.** HENRI ABRAHAM, *Professor of Physics at The Sorbonne, and General Secretary of the I.U.P.A.P.*
3. **Mathematical Considerations Underlying the Formulations of the Electromagnetic Equations and the Selection of Units.** LEIGH PAGE, *Professor of Physics, Yale University.*
4. **A Definitive System of Units.** GEORGE A. CAMPBELL, *Research Engineer, American Telephone and Telegraph Company.*
5. **The Establishment and Maintenance of the Electrical Units.** HARVEY L. CURTIS, *Physicist, U. S. Bureau of Standards.*
6. **Possible Extensions of the Existing International Series of Electric Units (ohm, volt, ampere, coulomb, farad, henry, joule, watt) into a Complete Absolute System.** A. E. KENNELLY, *Professor Emeritus of Electrical Engineering, Harvard University.*

ABSTRACTS OF CONTRIBUTED PAPERS

MONDAY MORNING AT 9:30 O'CLOCK

Eckhart Hall, Room 133

Papers Nos. 1, 2 and 3 will be read by title.

1. Efficiency of Chemiluminescence Accompanying Oxidation of Grignard Compounds. CLARENCE DELMAR THOMAS, *Missouri School of Mines (Rolla), and* R. T. DUFFORD, *University of Missouri (Columbia).*—The chemiluminescence which accompanies the reaction of certain Grignard reagents with oxygen has been studied quantitatively. The input energy, assumed equal to the heat of oxidation, was determined for sixteen compounds, by special calorimetric methods adapted to use with such highly reactive substances. The amounts of material used were found by titration. The luminous output was measured with a specially-built sphere photometer; the curves of mean spherical candlepower against time were integrated to find the total energy radiated. On the basis of 620 lumens per watt, the efficiencies can be computed for the luminescence. The values obtained range from about 10^{-7} to 2.6×10^{-5} percent, the highest values being given by p-ClC_6H_4MgBr. (See also the accompanying abstract by Asling and Dufford.)

2. Efficiency of Chemiluminescence Accompanying the Wedekind Reaction. WALTER LOUIS ASLING, *Missouri Wesleyan College (Warrenton), and* R. T. DUFFORD, *University of Missouri.*—The chemiluminescence accompanying the reaction of certain Grignard reagents with chloropicrin has been studied quantitatively. The input energy, assumed equal to the heat of reaction, was measured for eleven compounds, by using specially adapted calorimetric methods. The luminous output was measured with a specially built sphere photometer, the methods used being similar to those of Thomas and Dufford (see accompanying abstract). The efficiencies measured range from 4.4×10^{-6} percent to 10^{-9} percent. The significance of these values with regard to the possible origin of the luminescence is discussed.

3. New Observations on the Photovoltaic Effect. R. T. DUFFORD, *University of Missouri.*—The behavior of a number of types of photovoltaic cell, especially cells containing Grignard solutions, is studied and compared with that of other types of cells. The need for extension of current theories of electrode potentials in order to explain the phenomena is pointed out, and a possible direction along which such extension might be made is suggested.

4. Electrical Characteristics of Barrier-Layer Photo-Cells. PAUL R. GLEASON, *Colgate University.*—The resistance of barrier-layer photo-cells has been determined over a wide range of illumination and for currents both in the same and the opposite direction to the photocurrents. The bridge circuit used had to be compensated for the voltaic effects of the cells. The general shape of the curves agrees in the one case with those for photoconducting selenium cells and with the curves for contact rectifiers in the case of the variation with the current through the cell. The results for the Photronic cell are not in agreement with those of Romain (Rev. Sci. Inst. **4**, 83 (1933)). He gave a linear relation for the variation of the conductivity with illumination and also with leakage current. One cuprous oxide cell made in this laboratory exhibited unusual characteristics. The current output was at least one-tenth that usually obtained for cuprous oxide cells (Vorderwand) in spite of the fact that the cell shows practically no rectification for currents comparable with the photocurrents. Waibel and Schottky (Phys. Zeits. **33**, 583 (1932)) stated that such cells yield about 0.0001 the current of the rectifying cells. For higher values of the current, this cell is unusual in giving a rectified current in the same direction as the photocurrent.

5. The Photoelectric Properties of Magnesium Layers. G. DÉJARDIN AND R. SCHWÉGLER, *University of Lyons.*—The photoelectric sensitivity of magnesium has been carefully studied, by using a mercury arc and a hydrogen tube giving an intense continuous emission in the ultraviolet. The energy emerging from the monochromator was measured by a Moll thermopile or, for greater convenience, was deduced from the response of a calibrated potassium cell, sensitized by coating the window with a fluorescent mixture of sodium salicylate and dextrine. Between 3400 and 2300A, the effective sensitivity of this cell is accurately proportional to λ. The spectral distribution curve is nearly the same for mirrors obtained on glass by evaporation of pure magnesium in highly exhausted bulbs, and for the layers deposited on nickel by sputtering in argon. The sensitivity has no maximum between 2100A and the threshold, which occurs at 3400A. Near 2537A, the mean value of the yield is 10^{-4} amp. watt. The long wave limit is usually shifted above 4000A for layers produced in poor vacuum, but the yield never rises to the exceedingly large value indicated by De Laszlo. Bright mirrors obtained by evaporation of a magnesium and barium alloy have their threshold above 5000A and the spectral curve shows a singularity about 3400A. In combination with appropriate filters, a MgBa cell is suitable for measuring the erythemal output of quartz mercury lamps.

6. Effect of Temperature on the Energy Distribution of Photoelectrons. W. W. ROEHR AND L. A. DUBRIDGE, *Washington University, St. Louis, Mo.*—An extended experimental test has been carried out of the theory of energy distribution recently developed by DuBridge (Phys. Rev.

43, 727 (1933)). Photoelectrons were released by monochromatic light from an outgassed filament of Mo placed at the center of a large collecting sphere connected to an FP54 amplifier. Photocurrent measurements at filament temperatures up to 1000°K were made possible by heating the filament with the interrupted current furnished by a special thyratron circuit. The results obtained are in complete quantitative agreement with the theory and show: (1) The "temperature tails" to the current-voltage curves are appreciable at room temperature and become rapidly more pronounced at higher temperatures. (2) For a *clean* surface at room temperature the most probable energy is about 0.85 of the (extrapolated) maximum and shifts to lower values for high temperatures. (3) The observed curves show an excellent fit to the theoretical curves for the whole range of temperatures and wave-lengths examined. (4) From the shifts required to fit the observed curves the maximum energy at 0°K can be determined, and the values so obtained for a series of different wave-lengths at any fixed temperature fit closely the Einstein equation.

7. Progress Report on the Electrostatic High Voltage Generator at Round Hill. L. C. VAN ATTA, E. W. SAMSON* AND R. J. VAN DE GRAAFF, *Massachusetts Institute of Technology.*—Preliminary trials have been made with one of the two units comprising the electrostatic high voltage generator at Round Hill (Phys. Rev. **43**, 149 (1933)). A current of 0.75 milliampere was delivered to the sphere by a single experimental paper belt three feet wide running self-exciting at 5600 feet per minute. A current of 2 milliamperes is expected in the second unit with a charging assembly now under construction consisting essentially of two belts each four feet wide. Details of the charging mechanism will be given, together with the results of voltage measurements to be made on the completion of the second charging assembly. Sufficient voltage and power for nuclear research are now assured, and the construction of a vacuum tube of the type previously described (Phys. Rev. **43**, 158 (1933)) has been started.

8. The Exponential Law of Radioactive Disintegration. ARTHUR E. RUARK, *University of Pittsburgh.*—The radioactive decay law $N = N_0 e^{-\lambda t}$ is based on the assumption that the probability w for an atom to disintegrate in unit time is constant. The question arises, if the exponential law is accurately followed, can we conclude that w is independent of the age of the atom? It might happen that atoms of different ages have different decay probabilities; and w might depend on age in such a way that exponential decay curves result. Wolfke has shown, however, that w cannot depend on the age of the atom. To generalize this, suppose the members A, B, etc. of a series to have decay probabilities w_A, w_B, etc. Then we can demonstrate the theorem, if all members decay exponentially; and if each w is at most a function of the age of the atom, the ages of its ancestors and the ages of its descendants; then the w's are constant. Therefore, the assumption of constant probability of disintegration in unit time, which is the basis of all theories of disintegration, is necessary as well as sufficient.

9. The Disintegration of the Elements by Swiftly Moving Protons. M. STANLEY LIVINGSTON, MALCOLM C. HENDERSON AND ERNEST O. LAWRENCE, *University of California.*—Using our apparatus for the multiple acceleration of ions to high speed we have bombarded various elements with protons ranging in energy from 600,000 to 1,600,000 volts and in every instance have obtained evidence of disintegration. Li yields alpha-particles of 8.5 and 9.1 cm range when bombarded by protons of 600,000 and 1,400,000 volts respectively. The difference in range corresponds to the difference of proton energies and proves that the process involves capture of the proton. Be yields 3.3 cm alpha-particles and a few with ranges as great as 6.1 cm. The low energy group have an excitation threshold of 900,000 volts. NaCl yields alpha-particles with ranges up to 3.4 cm when bombarded by 1,100,000 volt-protons. A few 2.7 cm alpha-particles were observed from both Al and Mg (commercial purity) and still fewer 2.2 cm alpha-particles from NH_4NO_3 when bombarded by 750,000 volt-protons. There is a possibility at the present time that some of the observations are due to impurities. This possibility we are investigating.

10. Three Types of Nuclear Disintegration of Calcium Fluoride by Bombarding Protons of Very Great Energy. ERNEST O. LAWRENCE AND M. STANLEY LIVINGSTON, *University of California.*—Calcium fluoride when bombarded by swiftly moving protons yields alpha-particles of three distinct ranges. Protons of energies between 600,000 and 950,000 volts produce alpha-particles of 2.8 cm range. Between 950,000 and 1,350,000 volts the protons produce both 2.8 cm and 5.6 cm alpha-particles; while from 1,350,000 volts to 1,600,000 volts an additional alpha-particle group of 6.8 cm range is excited. The thresholds for excitation of these alpha-particle groups are sharp and the yield in each case rapidly increases linearly with increase of the range of the protons above the threshold value. For example, the yield of 6.8 cm alpha-particles increases tenfold for protons between 1,400,000 and 1,600,000 volts.

11. The Disintegration of Nuclei by Swiftly Moving Ions of the Heavy Isotope of Hydrogen. GILBERT N. LEWIS, M. STANLEY LIVINGSTON AND ERNEST O. LAWRENCE, *University of California.*—Using a sample of hydrogen containing fifty percent of the heavy isotope, H^2, we have produced 2,000,000 volt H^2H^1 ions. These ions striking any target immediately yield 660,000 volt-protons and 1,330,000 volt H^2 nuclei which we call deutons. Eight targets were used and in every case disintegration with emission of alpha-particles was observed. LiF yields large numbers of alpha-particles of two ranges, 8.2 cm and 14.8 cm. The latter, corresponding to an energy of 12,600,000 volts, are the highest speed alpha-particles yet observed either from natural or artificial disintegration. NH_4NO_3 gives many alpha-particles with range 6.8 cm which are almost certainly due to N. This element is of especial

* National Research Fellow.

interest because it typifies elements of nuclear type $4n+2$. Al, Be and Mg, all of only commercial purity, give alpha-particles of 6.8 cm, 3.3 cm, and both 3.3 and 6.8 cm, respectively. NaCl, CaF_2 and B_2O_3 gave 2.8, 3.8 and 4.4 cm alphas respectively. In these three cases the results may be due to the proton alone. With Li the disintegration was obtained with deuton energies as low as 300,000 volts. With N and Be definite disintegration thresholds were observed, both at 600,000 volts, while with Al no disintegration was observed below 1,100,000 volts.

12. Production of Neutral Rays of Several Hundred Ion-Volt-Equivalent, the Absolute Measurement of Their Intensity, and the Ionizing Function of Argon Rays in Argon. OTTO BEECK, *California Institute of Technology.*—Earlier experimental investigations and theoretical considerations suggested that the possibility of ionizing any atom by any stable atom or ion of equal energy is largest if the atom is struck by its own atom. A method has been worked out to produce a strong monochromatic beam of atomic rays up to several hundred ion-volt-equivalent and to measure its absolute intensity by a thermo-method. Thus having laid the ground for a large variety of investigations, first the ionizing function of A° in A was investigated between 350 and 650 ion-volt-equivalent. The quantitative values were found about 4 times as high as in the collision of K^+ and A at similar energies.

13. On Neutrons from a Beryllium-Radon Source. J. R. DUNNING AND G. B. PEGRAM, *Columbia University.*—Further studies of Be-radon neutrons have been made by using the linear amplifier-oscillograph-Thyratron detector system as described previously (Phys. Rev. **43**, 497 (1933)) in a large room and with a thin-walled ionization chamber, both to minimize effects of scattered neutrons. Absorption curves have been obtained for C, Al, Pb, Cu, and paraffine up to 21 cm thickness, and single points for 4 cm thickness of a number of other elements, with the residual scattering reduced to about 1 percent. Since absorption is largely scattering, the form of the curves is a function of the type and distribution of material, and must be interpreted in terms of angle scattering functions and multiple scattering of the neutrons. These measurements are in general agreement with the theory developed by Professor I. Rabi treating scattering as an elastic sphere collision between neutron and nucleus on a wave mechanics basis, with a radius for the neutron of the order of 1.3×10^{-13} cm. Further scattering measurements have been made for C, Al, Cu, Sn, and Pb, at angles between 45° and 135°. When a beam of neutrons was sent through a magnetic field of 10,000 gauss, 15 cm in length, no measurable deflection was observed, indicating that the neutron does not have the properties of a free magnetic pole of any large multiple of unit strength. The angle distribution of neutron emission has been studied using a source in which the beryllium was bombarded with alpha-particles from one direction only. Approximately twice as many neutrons are recorded in the forward direction as in the backward direction, after being filtered through either 5 or 8 cm of lead.

MONDAY MORNING AT 9:30 O'CLOCK

Eckhart Hall, Room 202

Paper No. 14 will be read by title.

14. Probable Errors of the Parameters in an Empirical Formula. W. EDWARDS DEMING, *Bureau of Chemistry and Soils, Washington, D. C.*—In the situation where only one coordinate of each point is subject to errors of observation, and where there are no rigorous relations between the parameters, systematic procedures are well known for computing the probable errors of the parameters evaluated by the method of least squares. For much of the work in physics the situation just described is not general enough, because oftentimes more than one coordinate of each point is subject to error, and the parameters may not all be independent. A methodical process is now given for solving and checking the results to obtain the probable errors of the parameters in the general case. The squares of the probable errors in the parameters $a, b, \cdots, p$ turn out to be

$$t_a^2 = t^2\{A_1 - A_1(A'F_a^{n+1} + A''F_a^{n+2}) - A_2(A'F_b^{n+1} + A''F_b^{n+2}) - \cdots - A_p(A'F_p^{n+1} + A''F_p^{n+2})\}$$

$$t_b^2 = t^2\{B_2 - B_1(B'F_a^{n+1} + B''F_a^{n+2}) - B_2(B'F_b^{n+1} + B''F_b^{n+2}) - \cdots - B_p(B'F_p^{n+1} + B''F_p^{n+2})\}$$

etc., wherein $A_1, A_2, \cdots, A_p, A', A''$ are the values of $a-a_0, b-b_0, \cdots, p-p_0, \lambda_{n+1}, \lambda_{n+2}$ that are obtained by replacing the constant column of Eqs. (13) in the general solution (Phil. Mag. **11**, 146 (1931)) by 1, 0, 0, $\cdots$, 0; $B_1, B_2, \cdots, B_p, B', B''$ are obtained by replacing the constant column by 0, 1, 0, $\cdots$, 0; etc. t is the probable error of an observation of unit weight.

15. A Fundamental Connection Between Hamiltonian Dynamics and Wave Mechanics. CORNELIUS LANCZOS, *Purdue University.*—Field equations which are deduced from a variational principle can be considered in the function space to represent the dynamical problem of a moving mass point. The variational principle is the "Hamiltonian principle" of this dynamics. The Lagrangian equations of motion are equivalent to the given system of field equations. Introducing instead of Lagrange's dynamics, Hamilton's dynamics the canonical equations of motion and canonical transformations are obtained: they are equations of first order while the number of variables is doubled. The possibility of canonical transformations can be used

for prescribing special requirements that the Hamiltonian function shall satisfy. We require that the canonical equations of motion shall form a *self-adjoint* system of differential equations. The 4 field equations of the vector potential may then be written as 2 complex equations of second order. The coordinated canonical equations of motion in the Hamiltonian dynamics of the function space result in a system of 4 complex equations of first order: they are Dirac's equation of a free electron.

16. A Canonical Coordinate System in Riemannian Geometry. EDWARD L. AKELEY, *Purdue University.*—Let $(\lambda_1 \cdots \lambda_n)$ be the characteristic values of λ associated with the pencil of tensors $G_{\mu\nu} - \lambda g_{\mu\nu}$, where $g_{\mu\nu}$ is the Riemannian metric tensor, and $G_{\mu\nu}$ its contracted Riemann-Christoffel tensor. If $\partial(\lambda_1 \cdots \lambda_n)/\partial(x_1 \cdots x_n) \neq 0$, the λ's form a canonical coordinate system. If $g_{\mu\nu}dx_\mu dx_\nu = \bar{g}_{\mu\nu}d\lambda_\mu d\lambda_\nu$, the $g_{\mu\nu}$ form a set of invariants which completely characterize the geometry. For these geometries, in addition to the parallelism of Levi-Civita, there exist definable types of integrable distant parallelism. Furthermore, certain Euclidean geometries can be invariantively associated with such a geometry. For $n=2$ no geometries of this type exist. For $n>2$ it is shown that they do exist, and some of their properties, in particular, in the neighborhood of the origin, have been studied.

17. On E. A. Milne's Theory of World Structure. H. P. ROBERTSON, *Princeton University.*—The theory of world structure recently proposed by E. A. Milne (Zeits. f. Astrophys. **6**, 1–95 (1933)) is found to rest on a postulate which is equivalent to that on which the theory of relativistic cosmology is based, thus disposing of his most fundamental objections to the latter theory. From one standpoint Milne's theory may be considered as the kinematical preliminary to the dynamical problem which is completely solved, in accordance with the general relativity theory of gravitation, by the so-called expanding universe theory; from another, consistent with that on which Milne's prediction of the linear velocity-distance relationship is obtained, it is interpretable as a special case of the alternative theory in which the influence of matter on the structure of the universe is considered negligible. The gravitational extension of Milne's solution, considered from this latter point of view, leads to an expanding universe which differs inappreciably from it unless the density of all matter in the universe exceeds Hubble's lower limit of 5×10^{-31} g/cm^3 by at least a hundred-fold.

18. Binding Forces in the Alkali Metals According to the Free Electron Theory. O. K. RICE, *Harvard University.*—Although there have been a considerable number of attempts to work out in some detail the nature of the cohesive forces in the alkali metals, it has seemed worth while to see how far one could go with the simplest possible hypothesis, according to which the metal consists of singly charged positive ions imbedded in a sea of free electrons. Frenkel first showed that the fact that the electrons in the metal obey the Fermi statistics, results in an effective repulsive force which will be balanced by attractive electrical forces; but, as he pointed out, the finite size of the ions prevents this being more than a qualitative picture, and he suggested taking this into account by including repulsive forces between electrons and ions. In the present work, I have introduced an intrinsic ionic volume, into which the electrons are supposed to be unable to penetrate, this simply being subtracted from the atomic volume in the Fermi expression for the kinetic energy of the electrons. For the attractive potential an expression involving a Madelung constant of a size about equal to those occurring in cases of uniunivalent crystals, and the same for all the alkali metals, is used. One can then calculate the energy of the metals from the experimental value of the atomic volume, getting excellent agreement with experiment. The method is not so successful in calculating the compressibilities; but, aside from the fact that the compressibilities at absolute zero may only be inferred from measurements around room temperature, it appears that a relatively small correction to the Fermi energy expression can give the correct compressibility without greatly upsetting the calculation of the energy. The latter is, then, to be considered as significant.

19. Distribution of Conduction Electrons in d.c. Currents. ERNST WEBER, *Polytechnic Institute of Brooklyn, Brooklyn, New York.*—A new series of experiments is described (Phys. Rev. **43**, 781A (1933)) in which magnetic fields perpendicular to a large conductor carrying direct current of several hundred amperes are used. These experiments bear out the fact that the current distribution in the conductor depends upon the length over which the magnetic field is applied. Different arrangements are used to explore the current distribution over the entire conductor and to measure simultaneously the temperature distribution. It is intended to investigate this new effect of low magnetic fields upon large currents also for materials other than copper.

20. Magnetic Force and the Law of Action and Reaction. FORREST F. CLEVELAND, *University of Kentucky.* (*Introduced by F. W. Warburton.*)—The classical expression, $d\bar{f} = i(d\bar{s} \times \bar{H})$ where $d\bar{H} = i(d\bar{s}' \times \bar{r})/cr^3$, for the force on a current element in a magnetic field predicts that the force exerted on one side of a rectangular circuit by the other three sides *is not equal and opposite* to the force reaction on the three sides. Experimental evidence is presented to show that these forces are equal and opposite and hence that the classical expression is invalid for this partial circuit. Ampere's expression for the force between current elements,

$$d^2\bar{f} = -\frac{ii'}{c^2r^3}\bar{r}\left[2(d\bar{s}' \cdot d\bar{s}) - \frac{3}{r^2}(d\bar{s}' \cdot \bar{r})(d\bar{s} \cdot \bar{r})\right]$$

when applied to this circuit predicts that the law of action and reaction should hold, thus offering, apparently, greater promise for calculations involving partial circuits than the classical force equation.

21. Electric Waves, Derived from Weber's Energy Equation. F. W. WARBURTON, *University of Kentucky.*—

An auxiliary vector $\bar{G}$, defined as equal, both in magnitude and direction, to the magnetic force per unit length on a current, corresponds, when using Ampere's law of force between current elements, to the classical magnetic field $\bar{H}$. Weber's energy equation is applied to a system of two moving electrons and two positive charges, a source, $-e'(v')$ and $-e'$, and an absorber, $-e(v)$ and $-e$. $\bar{G}$ and the electric field $\bar{E}$ may be found from the space and time rates of change of the mutual energy. Div $\bar{G}$ contains the factor $2(\bar{v}\times\bar{r})\cdot(\bar{v}'\times\bar{r})-(\bar{v}\cdot\bar{r})(\bar{v}'\cdot\bar{r})$, while $\partial E/c\partial t$ contains $(\bar{v}\times\bar{r})\cdot(\bar{v}'\times\bar{r})-2(\bar{v}\cdot\bar{r})(\bar{v}'\cdot\bar{r})$, and their difference yields

$$\nabla^2\bar{A}=\frac{\mu\epsilon}{c^2}\frac{\partial^2\bar{A}}{\partial t^2}-\frac{\mu e'\bar{v}'\cos\beta}{cr^3\cos\theta},$$

where A is the vector potential, directed along r, and β, θ are the angles between v and v', v and r. This wave is homogeneous in the region between the source and the absorber ($\cos\beta=0$), but on reaching the absorber it represents the variation in mutual potential energy of source and absorber, governing the transfer of energy to the latter. The interpretation is that a change in energy of the source is propagated with velocity $c/(\mu\epsilon)^{\frac{1}{2}}$ and may be absorbed by the first electron ($\cos\beta\neq0$) which it reaches.

22. Reflection of a Spherical Light-Wave from a Moving Plane Mirror. N. GALLI-SHOHAT, *Helen Schaeffer Huff Memorial Research Fellow, Bryn Mawr.*—When a spherical wave meets a moving plane mirror, the locus of the points in space where individual rays meet the mirror is a concave or convex surface according to whether the mirror is approaching or receding. From this surface reflection occurs as if it were a *fixed mirror*. This can be shown by applying Huyghens Principle (as it was done before for a plane wave by Hicks, Righi, Hedrick). A sufficiently small part of the spherical wave can be considered as a plane wave. We can construct for such an elementary wave a fixed mirror (in the above sense). We find that such a mirror is turned relative to the actual one by

$$\angle\alpha=|(v_N/c)\sin\varphi+(v_N^2/c^2)\sin 2\varphi+\cdots|;$$

hence, the reflected ray rotates by 2α (v_N-perpendicular component of v to the mirror, φ angle of incidence). We further show that in the first order the reflected wave is a spherical wave, its center being the virtual image of the source of light. Furthermore, due to the motion, object and image distances p_0, q_0, equal for the plane mirror, change to $p_0(1\pm v_N/c)$ and $q_0(1\mp v_N/c)$ from which the focal length of the fixed mirror can be found. In the second order individual rays appear as coming from different points of the axis, and the virtual image is thus distorted.

23. The Reflection of Plane Wave Pulses from Plane Parallel Plates. MORRIS MUSKAT, *Gulf Research Laboratory, Pittsburgh, Pa.*—A wave theory analysis has been developed for the reflection of wave pulses from plates, which heretofore has been treated by the methods of geometrical optics. The general theorem is proved that if the reflection coefficient for a harmonic wave system is exactly periodic in the frequency of the waves, the reflections from the plate due to an incident pulse will consist of a series of wave trains of exactly the same form as the incident pulse. This theorem may be applied to electromagnetic waves polarized in and normal to the plane of incidence, longitudinal waves in fluid media, and transverse waves polarized normal to the plane of incidence in general elastic media. For problems involving more than two interfaces or for waves in general elastic media in which both longitudinal and transverse waves are excited, the reflection coefficients possess terms of several periodicities which are, in general, incommensurable with each other. By expansion into series consisting of terms of a single periodicity, each term will again give wave pulses which are undistorted with respect to the incident pulse. The resultant reflected wave systems, however, will show an apparent distortion due to the overlapping of the separate pulses.

MONDAY MORNING AT 9:30 O'CLOCK

Ryerson Physical Laboratory, Room 32

24. The Structure of Rubber as Shown by the Time Lag of Fibering. W. E. SINGER, J. D. LONG AND W. P. DAVEY, *The Pennsylvania State College.*—The authors have found by x-ray methods that there is a time lag between the time when rubber is stretched and the time when a fiber structure is produced. Rubber must be of such a nature and such a structure as to account for the following characteristics: (1) A more or less critical temperature limit for the time lag of fibering. (2) A time lag of fibering unaffected by stretching the rubber above this critical temperature and then cooling rapidly. (3) A higher percentage stretch required to develop the fibrous structure after mechanical working and aging. (4) A relaxation time of less than 0.5 second. (5) A time lag of fibering independent of the length of time the rubber is held stretched, at least between 2 and 5 seconds. (6) A shorter time lag of fibering with a slow rate of stretching. (7) The enormous extensibility of rubber. All this mass of data is consistent with the picture that rubber consists of a tangle of spiral (or zigzag) shaped molecules whose ends are rather firmly anchored, but whose lengths can be temporarily untangled by the application of an external force.

25. Elastic Constants of Zinc. ALVIN W. HANSON, *University of Iowa. (Introduced by E. P. T. Tyndall.)*—The elastic constants of zinc have been determined by static torsion and bending experiments. The bending experiments were performed on single crystals of 0°, 45°, and 90° orientation; the torsion experiments on crystals

of 0°, 70°, and 90°. From these measurements three constants are directly determined and certain combinations among the constants are obtained from which the remaining two constants may be computed. The crystals used in the bending experiments were of square cross section, about 7 mm on a side. Those used in the torsion experiments were of circular cross section, approximately 6 mm in diameter. The crystals were grown in a horizontal electric furnace under conditions which would insure the least possible strain. Strained crystals were found to give variable results.

26. Hooke's Law and Crystal Structure. A. E. CASWELL, *Oregon State College, Corvallis, Oregon.*—Cohesion between atoms and molecules in solids and liquids is usually assumed to be due to electrostatic or magnetic attractions and the derived force equations contain as one factor some inverse power of the distance between centers of force, that is, of the spacing. Unquestionably these forces play an important part in cohesion but fail to account for Hooke's law of elasticity according to which the force of restitution is directly proportional to the change in the spacing, either in extension or compression. It is shown that if in a crystal or other solid the atoms are arranged so that in various directions there are rows of electron orbits with the orbits in each row perpendicular to the direction of the row, relatively close together and with the electrons revolving in the same direction, so each row resembles a miniature solenoid, Hooke's law follows. When the spacing is increased until a row of orbits fails to behave as a solenoid Hooke's law no longer holds and the substance has passed its elastic limit. In diamagnetic substances each row of orbits is matched by an equivalent row or rows in which the electrons revolve in the opposite direction.

27. Crystallization of Polymorphous Substances I. K. LARK-HOROVITZ AND S. E. MADIGAN, *Purdue University.*—The stability of a compound in a polymorphous system is determined by the thermodynamic potential of the pure compound and the interaction between the compound and the support on which the crystallization takes place. The cubic form of ZnS—zincblende—has been evaporated in vacuo at temperatures well below the transition point $\alpha-\beta$ZnS and deposited on various surfaces held at 20°C. The deposit formed was cubic on all surfaces with a cubic lattice (copper, aluminum, diamond, etc.) and on amorphous surfaces (glass, fused, quartz). It also remained cubic on pure zinc and mica or crystalline quartz. On zinc oxide a mixture of the hexagonal modification—wurtzite—with an abundance of cubic modification has been formed. The deposit of ZnS on hexagonal cadmium sulphide is almost purely hexagonal—wurtzite—independent of temperature or pressure conditions. ZnS has been deposited simultaneously on hexagonal cadmium sulphide and on copper surrounding the cadmium sulphide. The deposit was hexagonal on cadmium sulphide and cubic on the copper. Wurtzite when evaporated in vacuo is deposited on cubic surfaces cubic—as zincblende—but remains wurtzite if deposited on hexagonal ZnS.

28. A Resistance Function for Dense Fluids. LOUIS THOMPSON, *Naval Proving Ground, Dahlgren, Va.*—Experiments conducted with projectiles in unstable motion through short water ranges have led to the result that the order of retardation can be predicted by means of the air resistance function, provided that a coefficient for unstable flight in air is introduced. Because of the inherent instability of the motion, large variations occur in the path of the water runs of the projectile from round to round and quite irregular changes of course in the same run. The retardation data are subject to large variations and the rough approximation afforded by the resistance function is probably as satisfactory as any to be had as far as the prediction of performance in any specific case is concerned. The resistance is $R=(\rho/\rho_0)i(V,\theta)V^2L^2\bar{F}$, where $\bar{F}\equiv F(V/V_S, VL\rho/\mu)$ for air, taking mean value for velocities of similar range of V/V_S, ρ density water, ρ_0 density air, $i(V,\theta)$ factor, average value determined from range or retardation data for unstable flight in air. L diameter of projectile, θ angular deviation of the axis.

29. Fluidities of Thixotropic Gels: Bentonite Suspensions. H. A. AMBROSE AND A. G. LOOMIS, *Mellon Institute of Industrial Research and Gulf Research Laboratory, Pittsburgh. (Introduced by Paul D. Foote.)*—Flow measurements on bentonite suspensions, showing both the property of thixotropy, and of fluidity variable with shearing stress, were performed in capillary tubes, brass pipes, and a rotary consistometer of special design. The latter instrument was used to show that the structure of such gels must be broken down or built up until an equilibrium state of flow is attained to obtain reproducible measurements. No slippage at the walls was found in non-plug flow. Turbulent flow of bentonite suspensions was investigated in one-half and one inch pipes. It is shown that these materials behave as any viscous liquid, in the turbulent region, and that the volume of flow at any pressure gradient may be assumed to be the same as for water, without great error. The importance of obtaining equilibrium flow conditions for fluidity measurements is stressed.

30. A New Visco-Conductimeter. J. V. HOFFACKER AND C. L. BABCOCK, *Purdue University. (Introduced by K. Lark-Horovitz.)*—Two platinum cylinders having diameters of 1 inch and 1/4 inch are arranged concentrically and the interspace is filled with the liquid under investigation. With a special gear train the rotating speed of the outer cylinder can be varied from 3.48 radians per second to $3.48\times10^{-8.74}$ radians per second. The torque on the inner cylinder due to the viscosity of the liquid is counterbalanced by using a specially constructed balance so that the torque can be read off directly as weight of a rider times lever arm (null method). The platinum cylinders serve also as electrodes and in this way resistance and viscosity are measured simultaneously. Polarization effects are avoided by using 500 cycle alternating current for the conductivity measurements. The instrument has been used for ordinary liquids at room temperature and for silicate glasses up to 1400°C and its results agree with results obtained by other methods.

31. Viscosity and Conductivity of Molten Glasses. C. L. BABCOCK AND K. LARK-HOROVITZ, *Purdue University.*—With the instrument described above, the conductivity and viscosity of different molten glasses has been investigated as a function of temperature up to 1400°C by taking measurements about 50°C apart. It has been shown that in no case is there a sudden break in the viscosity or conductivity curves as functions of temperature; neither one can be represented as a simple exponential of $1/T$. Conductivity and viscosity are not simply proportional but can be represented over the whole temperature range from softening point (e.g., 700°C for H.E. soda lime, 750°C for 702 EJ) up to about 1400°C by a formula $\eta = A\rho^B$. In this equation A and B change from glass to glass: therefore, the process of conductivity and viscosity cannot be based on the same principle, but the experiments point to the fact that while viscosity is determined by aggregations in the glass and their change with temperature, conductivity takes place in the true liquid interstices.

32. The Beat Note-Combinational Tone Controversy. HERBERT HAZEL AND R. R. RAMSEY, *Indiana University.*—The Helmholtz-Koenig controversy, participated in by Lord Rayleigh, Preyer, Bosanquet, Waetzmann, Edser, Rucker, and others, is settled on the basis of the conditions for modulation. Experimental study of the conditions necessary for modulation shows that combinational tones or sideband frequencies are produced whenever a product term of the two parent frequencies is involved, regardless of whether linear or nonlinear response characteristics are used. Two periodic disturbances added in a linear medium do not cause response in a resonant circuit tuned either to a frequency equal to the difference between the two added frequencies or to a frequency equal to their sum. Experimental results using a linear wavemeter circuit as the analyzer were obtained with electromagnetic waves in the audio frequency band and in the radio frequency band. An electro-acoustical wave-meter, designed for response to sound waves between 500 and 5000 cycles per second, was used in the study of the addition of sound waves. Modulation of currents produced by an a.c. generator can be secured by varying the field strength of the generator. The process has been generally explained as one requiring a nonlinear magnetization curve. Using air-core coils we have found that modulation in the linear circuit occurs due to the product $(H_0+H \sin \omega_1 t) \sin \omega_2 t$.

33. Tone Analysis and Physical Characteristics of Violins. T. H. STEVENS AND R. B. ABBOTT, *Purdue University.*—A direct recording cathode-ray oscillograph has been used in conjunction with a condenser microphone and suitable amplifier to obtain steady state records of violin sound waves. The curves have been analyzed to twelve components, and studies made of factors characterizing violins of widely different tone quality; also, ways in which the tone quality of an instrument may be varied. Many resonance frequencies have been found, corresponding to natural vibration periods of the air cavity or of parts of the body. The distribution of energy among the components of the emitted wave is found to vary widely among various instruments, and gives a means of distinguishing between good and poor instruments as well as between "brilliant" and "dark" tones. Good carrying power is associated with considerable amplitudes in high order components. The effect of speed, pressure and position of the bow on the string has been given especial study. It is found that, within certain limits, increasing the pressure, or bowing nearer the bridge, cause relatively more of the radiated energy to be carried by lower order components. Extremely undesirable tones, described as squeaking or scraping, are found to be nonperiodic.

34. Some Frequencies of Multiple Resonators. RUTH O. JENKINS AND R. B. ABBOTT, *Purdue University.*—Frequencies at which a driving force was made to operate in order to locate resonance frequencies of a driven acoustical system were investigated in several cases. Electrical circuit analogies were the bases of mathematical investigations and specially designed vibration meters and stethoscopes were used to indicate resonance points. Sirens, tuning forks and closed organ pipes produced sound pressure for the driving force. In the case of two Helmholz resonators coupled in parallel, the wattless acoustical current was equated to zero giving an eighth degree equation with frequency as variable. $aw^8+bw^6-cw^4+dw^2-ew^0=0$. Two equal real and six imaginary roots satisfied the equation. The two real ones were found experimentally to exist as the equation required. A violin body can be considered as an air system coupled with two diaphragms, namely, the top and bottom. The air system is composed of two air resonators coupled in parallel. The diaphragms were made inoperative by packing the violin in sand. Four air cavity resonance points were located near 256, 512, 768, and 1024 cyc./sec. By using the same violin with top and bottom free to vibrate, the same resonance points were indicated by a vibration meter applied to back and front. Other violins gave similar results.

35. Study of a New Water Jet with Stroboscope and Camera. JOHN J. HOPFIELD, *Basic Science Division, A Century of Progress.*—Two small water jets that impinge at nearly a right angle form a leaf-shaped film jet with streamers tangential to its edges. In ordinary light both the streamers and the leaf-shaped film show stationary periodicity; the former doubtless due to the pulsation of the regularly spaced droplets that form them, and the latter to a series of fixed waves on its surface. The jet emits a high frequency note which can be changed by varying the spacing of the nozzles or the pressure of the water. Stroboscopic examination of the jet shows that ripples travel over the leaf-shaped film in the direction of flow, and impart to it a corded structure. The streamers are found to be made up of equally spaced droplets formed with the frequency of the ripples. Photographs of the jet taken with a rapidly moving film give much interesting data. Because of its relative simplicity a straight jet also was studied in an attempt to correlate the wave motion with the constants of the liquid. When the above double nozzle is used with a flame, a high frequency note is emitted.

Monday Afternoon at 2:00 O'clock

Ryerson Physical Laboratory, Room 32

Papers Nos. 47, 48 and 49 will be read by title.

36. On the Calculation of the Permeability of the Cell Surface to Oxygen. N. Rashevsky, *Westinghouse Research Laboratories, East Pittsburgh, Pennsylvania.*—An attempt is made to calculate the permeability of the cell surface to oxygen from oxygen pressure—oxygen consumption curves at low oxygen pressures. A mathematical study of such curves has been made by R. W. Gerard under the assumption that the only limiting factor for the penetration of oxygen into the cell is the coefficient of diffusion D. There is, however, another factor, the permeability h of the cell surface. The introduction of the latter into consideration means mathematically a different boundary condition for the diffusion equation. This leads to a different expression for the oxygen pressure—oxygen consumption curve and a good agreement with Gerard's data for fertilized Arbacia eggs is obtained with $D=7\times10^{-7}$ cm^2 min.$^{-1}$ and $h=4.2\times10^{-4}$ cm min.$^{-1}$. For some other cells no such agreement can be found. The meaning of this is discussed.

37. Sources of Positive Ions: Thermionic Properties of the System Li_2O, Al_2O_3, SiO_2. E. J. Jones and S. B. Hendricks, *Bureau of Chemistry and Soils, Washington, D. C.*—It is known (J. L. Hundley, Phys. Rev. **30**, 864 (1927)) that some compounds of Li_2O, Al_2O_3, and/or SiO_2 are satisfactory as thermionic sources of positive ions. We have used an arbitrary mixture $3Li_2O.1Al_2O_3.3SiO_2$ corresponding to a known compound and have found it to give constant emission of large currents (4×10^{-4} amp./cm^2) for long periods of time (40 hours). A similar material containing potassium was satisfactory as a source of potassium ions. The various compounds of Li_2O, SiO_2 and Al_2O_3 (see R. Ballo and E. Dittler, Zeits. f. anorg. Chem. **76**, 39 (1912) for an approximate equilibrium diagram) were prepared as homogeneous crystals and their thermionic properties were tested and found to be far superior to that mentioned above. The compounds were examined optically and by x-ray diffraction before and after prolonged use as thermionic sources in order to find the nature of the lattice changes accompanying the emission of positive ions.

38. An Effect of Space-Charge in Probe Analysis of a Plasma. R. H. Sloane, *Queen's University, Belfast and* K. G. Emeleus, *University of Michigan.*—By the use of a collector with mutually insulated sections to which different potentials could be applied, it has been shown, by using a low-voltage arc in argon, that under the special conditions of short collector and small electron concentration the positive ion sheath which forms on insulating surfaces near a collector in a plasma may lead to serious misinterpretation of the characteristics of the collector. The collector characteristics obtained have been analyzed in the conventional way for Maxwellian distributions, and by a newer method in which no initial assumption is made concerning the energy distribution other than that it is isotropic. The double differentiation of the characteristic in the second method is facilitated by making use of the identity $y^{-1}(d^2y/dx^2)=d^2\ln y/dx^2+(d\ln y/dx)^2$. The effect is twofold, first, a general diminution in the apparent concentration of electrons in the plasma, and, second, an apparent preferential suppression of the slowest electrons. Under most working conditions, these are probably inconsiderable at low pressure, but perhaps important at a pressure of a few mm and higher.

39. The Faraday Dark Space. K. G. Emeleus and O. S. Duffendack, *University of Michigan.*—The plasma diffusion theory of the negative glow and Faraday dark space gives no account of the optical structures observed. This is a preliminary report on new work on the Faraday dark space, mainly experimental. In helium further probe evidence is adduced to show that the region considered is a plasma. Tentative explanations are given of the failure of He_2 bands to appear in the negative glow, whilst they do appear in the Faraday dark space. It is found that with a trace of neon an almost isolated cap of neon light appears in the middle of the Faraday dark space, the He_2 bands being unaffected, whilst with a trace of nitrogen, nitrogen arc lines and negative bands replace He_2 bands. The resonances involved in the dissociation and excitation of the nitrogen are not clear, and are being further studied. The whole is consistent with there being an important contribution of metastable atoms to phenomena in the Faraday dark space, and it is suggested the phenomena there actually observed are those otherwise inferred from the experiments of Langmuir, Kenty and others on effects of impurities on propagation of resonance radiation through gases.

40. Self-Focussing Electron Streams. Willard H. Bennett, *Ohio State University.*—In cylindrically symmetric streams of electrons containing positive space charge just sufficient to neutralize the static charge of electrons, the mutual magnetic attraction of electrons gives a system whose parts act under an inverse square law of force. It can be shown that such a system is stable, and when the current exceeds a certain calculable value, the stream is self-focussing. Subject to certain restrictions with respect to initial stream conditions, collisions, and currents, the theory is applicable to several types of streams of charged particles and is necessary for an understanding of streams in high potential tubes.

41. Vibrating Velocity Selectors for Atomic Rays. J. Tykocinski Tykociner, *University of Illinois.*—Two types of velocity selectors have been constructed on the basis of the theory published in 1927 (J. Opt. Soc. Am.

14, 423 (1927)). In the first type each of the two vibrating parts consists of an aluminum plate 6×6 mm provided with a slit 3×0.03 mm and held in a magnetic field by two bronze ribbons and excentric rollers. By adjusting the latter the slits of the vibrating systems may be aligned. The natural frequency of the slit system is 750 per sec. Its range of velocity selection is from 50 to 150 m/sec. For larger velocities (300 to 900 m/sec.) serves the second type of selector in which the mass of the vibrating system has been considerably reduced by eliminating the aluminum plate. Two vibrating Duraluminum ribbons separated by a gap 0.02 mm define the width of the slit for the atomic rays. The natural frequency of the vibrating system has been thus increased to 7000 per sec. A thermionic oscillator combined with an amplifier supplies the driving alternating current adjustable from 3000 to 10,000 cycles per sec. At a frequency of 8750 a current of 0.08 amp. produces an amplitude of vibration equivalent to three times the width of the slit. The effect of the magnetic field, temperature and pressure on the amplitude of the slit has been investigated.

42. Application of a Vibrating Velocity Selector for the Determination of the Magnetic Moment of Hydrogen. JACOB KUNZ, *University of Illinois.*—Referring to the vibrating selector (see preceding abstract) preparations are nearly completed for a precise determination of the moment of H. The atoms produced by a high-frequency ring discharge pass through two Pyrex slits, then through the two slits of the selector and then through the non-homogeneous magnetic field and strike the molybdenum target. A most unusual difficulty has been overcome arising from the necessity of aligning four slits and the edge of pole pieces. Two of the slits being 0.02 mm wide produced diffraction of a beam of light so that the usual optical method of alignment failed. The method finally adopted consists in the use of three transit telescopes, two of which are centered on the slits and the third is focussed on the slits by means of a right-angle prism.

43. Rate of Vaporization of Molybdenum in Vacuo. LAWRENCE NORRIS AND A. G. WORTHING, *University of Pittsburgh.*—The changes in weight of various long filaments of molybdenum electrically heated in vacuo to various incandescent temperatures have been the basis of this study. In all cases two nearly identical filaments were mounted in a single bulb. Both filaments were heated to 2150°K by the same current during a 20 minute aging period. Thereafter only one of the two filaments was operated at the desired temperature until completion of the vaporizing period. To avoid the cooling effects of the supports, only central portions of the filaments were used in determining weight losses. Contrary to what might normally be expected, but in agreement with what one of the authors had found for tungsten, operation at constant current resulted very closely in constant temperature. When plotted the results are represented very closely for the temperature range $1600°K < T < 2400°K$, by an empirical equation of the form $\log m = A + B/T + C/T^2$. When m, the rate of vaporization, is expressed in g/cm² sec., and T in °K, A, B and C have values 7.57, -33.25×10^3 and 5.50×10^6. The values reported here for m are greater than those reported by Jones, Langmuir and Mackay by a factor of about 2.5 at 2400°K and of about 11.5 at 1600°K.

44. A New Method of Studying the Electrical Properties of Monomolecular Films on Liquids. H. G. YAMINS AND W. A. ZISMAN, *Harvard University.*—A new method is described for measuring the potential jump, dV, in passing through a monomolecular film floating upon any liquid. It has been found possible to measure dV by a null method to 0.001 volt in a few minutes of manipulation of a very simple apparatus. Obvious improvements in the amplifier employed will no doubt make it possible to measure dV to 0.00001 volt. Determinations of dV on films of oleic acid, palmitic acid, tricaprylin, trimyristin and trilaurin showed excellent agreement with the work of Guyot who used a much less satisfactory method due to Righi. The applications to the study of the polar moments and structure of organic molecules are pointed out. In particular the recent work of Fosbinder and Lessig on the study of protein structure and enzyme reactions is briefly discussed.

45. Single Electrode Potentials and the E.M.F. of a Cell. E. HUTCHISSON AND A. L. ROBINSON, *University of Pittsburgh.*—The e.m.f. of a cell has been obtained by summing the potential differences at the metal-liquid and metal-metal interfaces (electrolyte at unit activity) calculated by applying a Born-Haber-Fajans' cycle. If ΔF_S, ΔF_I, ΔF_H and ΔF_ϕ represent the free energies of sublimation, ionization, hydration and electron emission, the e.m.f. of a Cu-Zn displacement cell becomes:

$$2(\text{e.m.f.}) = (\Delta F_S^{Zn} + \Delta F_I^{Zn} + \Delta F_H^{Zn^{++}} - 2\Delta F_\phi^{Zn}) - (\Delta F_S^{Cu} + \Delta F_I^{Cu} + \Delta F_H^{Cu^{++}} - 2\Delta F_\phi^{Cu}) + 2(\Delta F_\phi^{Zn} - \Delta F_\phi^{Cu}).$$

Although ΔF_ϕ enters into the single electrode p.d. it cancels out in the total e.m.f. Since the work functions are not accurately known, the single electrode p.d. (but not the calculated e.m.f.) have large uncertainties. It will be noted that the difference between the single electrode p.d. for Cu and Zn is only about 0.1 volt while the e.m.f. of such a cell is 1.1 volts, indicating that the metal-metal contact p.d. is almost equal to the e.m.f. Since the e.m.f. of a cell is usually known very accurately,

Metal and ion	Single electrode-electrolyte p.d. (volts)	E.m.f. of a (metal)-(hydrogen on Pt) cell	
		Calculated (volts)	Experimental (volts)
Li, Li^+	$+0.9 \pm 0.4$	$+2.95$	$+2.96$
K, K^+	$+0.3 \pm 0.2$	$+2.85$	$+2.92$
Na, Na^+	$+0.4 \pm 0.3$	$+2.71$	$+2.71$
Zn, Zn^{++}	-0.35 ± 0.2	$+0.77$	$+0.76$
Pb, Pb^{++}	-0.6 ± 0.3	$+0.14$	$+0.12$
Cu, Cu^{++}	-0.45 ± 0.1	-0.33	-0.34
Ag, Ag^+	$-0.55 + 0.01$	-0.76	-0.80

the cycle may be reversed and the more uncertain quantities calculated.

46. The Use of Triode Vacuum Tube Rectifiers to Supply Constant Voltage. L. A. RICHARDS, *Cornell University.*—Fluctuations in the a.c. power supply usually make it impossible to obtain constant d.c. voltage from a rectifier-filter circuit. If triode power amplifier tubes are substituted for the usual half wave rectifiers it has been found that a fairly steady d.c. output, E_{dc}, can be obtained by having changes in the a.c. line voltage, E_{ac}, automatically change the negative bias, E_g, of the triode grids. Several grid control circuits have given good results. The following data taken with triodes in the conventional full

I		II		III		IV	
Type 50 Tube		Type 50 Tube		Type 10 Tube		Type 10 Tube	
8.9 m.a. load		29.7 m.a. load		5 m.a. load		8.7 m.a. load	
E_{ac}	E_{dc}	E_{ac}	E_{dc}	E_{ac}	E_{dc}	E_{ac}	E_{dc}
104.2	535.4	105.5	431.8	106.3	1000.4	112.5	521.0
111.	534.7	110.	433.3	108.2	1000.4	116.3	523.0
117.	534.6	115.	433.2	110.2	1000.2	119.	523.2
121.	534.9	119.7	433.2	112.2	1000.6	125.	523.5
126.	535.8	125.2	432.9	114.4	1000.7	129.5	523.5
				115.9	1000.3	136.	525.0
				118.5	999.0		

wave battery eliminator circuit indicate the degree of regulation which may be attained. Another type of control circuit with a combination of a.c. and d.c. on the grids of the triode rectifiers gave the results shown by the fourth set of data. It seems likely that further refinements in the design and adjustment of the grid control circuits can give more precise regulation. It is evident that by use of suitable tubes steady d.c. at much higher voltage may be produced.

47. The Emissivity of a Non-Black Body. L. T. DEVORE, *The Pennsylvania State College.*—All bodies found in nature differ from the accepted black body, as defined by Kirchoff, by virtue of the fact that their indices of refraction differ from unity. An expression is derived to show the functional relation between the emissivity, wave-length, and temperature for a non-black body.

$$\epsilon_{(\lambda,T)} = [A^2 + B_0(C^{-1}\rho^{E/KT} + 1)^{-1}\lambda^2/(\lambda^2 - \lambda^2_m)]^{3/2}.$$

Assuming the existence of a single absorption band the emissivity at constant temperature takes the form,

$$\epsilon_{(\lambda)} = [A^2 + M\lambda^2/(\lambda^2 - \lambda^2_m)]^{3/2}.$$

A^2, M and λ_m of this equation have been determined for tungsten by taking three experimentally determined points from Hulburt's data. By using the values of the constants obtained in this manner to solve for the emissivities corresponding with other wave-lengths, the formula has been verified by the almost perfect agreement shown between the calculated and experimentally determined values of the emissivities.

48. A Tungsten Filament Lamp as a Standard Source for Radiation Measurements. L. T. DEVORE AND R. F. BAKER, *The Pennsylvania State College.*—A tungsten filament lamp with a quartz window has been designed to fulfill the following requirements: (1) A continuous spectrum, (2) A constant energy distribution, (3) Reproducible characteristics, (4) Measurable intensities throughout the spectral region, (5) Uniform emitting surface. The lamp has been constructed without cement seals in such a manner as to facilitate the replacement of filaments. Filament temperatures as high as 3400°K have been attained without destroying the filament. The calibration of the lamp consists in two essential details: (1) Temperature-current calibration, (2) Spectral emissive power-temperature calibration.

49. A New Method for Amplifying and Recording Small E.M.F's. H. E. MORGAN, L. T. DEVORE AND R. F. BAKER, *The Pennsylvania State College.*—The potential difference to be measured is applied to a sensitive galvanometer. The fluctuations of the galvanometer mirror cause a beam of light to play across the cathode of a photoelectric cell. As the angular displacement of the galvanometer mirror increases the light flux falling on the photoelectric cell cathode increases and the output of the photoelectric cell increases. The current from the photoelectric cell is recorded by means of a microampere recorder and the whole instrument is calibrated against a series of known potential differences.

MONDAY AFTERNOON AT 2:00 O'CLOCK

Ryerson Physical Laboratory, Room 33

Paper No. 52 will be read by title

50. Standard Wave-Lengths in the Copper Spectrum in the Region 80A to 650A. F. S. COOPER AND P. GERALD KRUGER, *University of Illinois.*—The copper spectrum has been photographed with a 21 ft. grating at 87° angle of incidence in the region 80A to 650A. Several hundred lines in Cu VI, VII, VIII and IX, have been observed. A strong line about every Angstrom has been chosen as a standard and its wave-length calculated by expanding the grating equation $n\lambda = e(\sin\theta - \sin\phi)$ as a power series about some chosen line. The coefficients are calculated from known wave-lengths. Al lines measured by Söderqvist and Edlin (Zeits. f. Physik **69**, 356 (1931)) in several orders and an unpublished list of oxygen lines which have been standardized by Edlin have served as primary standards. The

spectra of Co, Ni, Cu and Zn have been photographed in this region and a partial analysis of these spectra has been made.

51. Multiplets of O III, O IV, and O V in the Region 100A to 650A. P. GERALD KRUGER AND W. E. SHOUPP, *University of Illinois.*—The oxygen spectra have been photographed with a twenty-one foot grating at 87° angle of incidence in the region 100A to 650A. Several groups of lines have been found each of which extended over about one-half of an Angstrom on the plate. From these groups the following transitions in the oxygen spectra have been identified.

O III	$2s^22p^2\,{}^3P_{0,1,2} - 2s^22p3s\,{}^3P^0_{0,1,2}$
	$2s^22p^2\,{}^3P_{0,1,2} - 2s^22p3d\,{}^3D^0_{1,2,3}$
	$2s^22p^2\,{}^3P_{0,1,2} - 2s^22p3d\,{}^3P^0_{0,1,2}$
O IV	$2s2p^2\,{}^4P_{1/2,3/2,5/2} - 2s2p3d\,{}^4D^0_{1/2,3/2,5/2,7/2}$
	$2s2p^2\,{}^4P_{1/2,3/2,5/2} - 2s2p3d\,{}^4P^0_{1/2,3/2,5/2}$
O V	$2s2p\,{}^3P^0_{2,1,0} - 2s3s\,{}^3S_1$

The $\Delta\nu$ separations of lines in other multiplets, which have been observed previously, have been remeasured with the result that the oxygen term values are more accurately known than before.

52. Spectrum of Cb IV. R. J. LANG, *University of Alberta.*—The spectrum of columbium has been photographed from 2500 to 250A in the vacuum spark and from 2500 to 1250A in the spark in nitrogen. It has thus been possible fairly well to separate the lines of Cb IV and Cb III. In Cb IV besides the known triplet terms $(4d5s)^3D$ and $(4d5p)^3F^3D$, the further triplet terms have been located: the deepest term $(4d^2)^3F$ and $(4d^2)^3P$ $(4d5p)^3P$ $(5s5p)^3P$ and part of the second members of some of the deeper terms. The singlet term $(4d5p)^1P$ is also located. The spectrum of Cb III consisting of doublet and quartet combinations is very rich in lines throughout the ultraviolet and this is in the process of analysis.

53. The Fine Structure of H_α. R. C. WILLIAMS AND R. C. GIBBS, *Cornell University.*—While attempting to investigate the fine structure of the H_α line of hydrogen from gas containing a moderately concentrated amount of the heavier hydrogen isotope, we had the good fortune to obtain from Professor G. N. Lewis of the University of California a small supply of water containing approximately equal amounts of the two isotopes. By fairly prolonged discharge through the water vapor in a suitably cooled Wood tube it was found possible to accumulate sufficient hydrogen gas in the tube so that a discharge could be maintained without difficulty when those portions of the tube from which the discharge was to be photographed were immersed in liquid air. By using a three mm etalon spacing in connection with a three prism Zeiss spectrograph, interferometer patterns were photographed with the H^2 "doublets" spaced about half way between those of successive orders of H^1. With type IV C Eastman plates, microphotometer curves remarkably free from plate grain were obtained, thus enabling with the aid of appropriate intensity marks, the conversion of these curves to true relative intensity values. The patterns of H^2 are markedly sharper than those of H^1 and accordingly reveal a smaller half line width. The component separations and their relative intensities as revealed by an analysis of the intensity curves are substantially in agreement with recent theory and the $\Delta\lambda$ found between corresponding components in $H_\alpha{}^1$ and $H_\alpha{}^2$ confirm those reported by Urey, Brickwedde and Murphy.

54. Hyperfine Structure and Nuclear Spin of Tantalum. NORMAN S. GRACE, *Commonwealth Fund Fellow, and* EDWIN MCMILLAN, *National Research Fellow, at the University of California.*—The hyperfine structures of some tantalum arc lines have been resolved, using a Schüler tube source and a Fabry-Perot etalon crossed with a prism spectrograph. Almost all the lines in the spectrum have structure. λ5997 is clearly resolved into eight components, degrading toward the violet, with a total separation of 0.782 cm^{-1}. The presence of eight components indicates that either I or J has the value 7/2, and application of the interval rule shows that the other is of the order of 17/2. Seven other structures have been analyzed, and they can all be explained in terms of $I=7/2$, not in terms of $I=17/2$. This fixes the nuclear spin of tantalum at 7/2. The possibility of using hyperfine structures as a means of determining J-values of levels where these are not known, as is the case with tantalum, is shown.

55. Second Order Zeeman Effect in the Arc Spectrum of Mercury. J. B. GREEN AND R. A. LORING, *Ohio State University.*—Professor Condon has suggested in correspondence with us, that the displacement of the parallel component of Hg I λ5790 $^1P_1 - {}^1D_2$, which should show no Paschen-Back effect, might be accounted for by the second order perturbation caused by the closeness of the $^3D_1$ and $^1D_2$ levels. The $^1D_2$ level itself must be considered as partially a triplet level, for L–S coupling has completely broken down. This is clearly shown by measurements of the g-values of $^1D_2$ and $^3D_2$ which are 1.02 and 1.09, respectively, instead of 1.00 and 1.17, showing not only a distortion of the g-values, but a breakdown of the Pauli g-sum rule. Preliminary measurements of the displacement of the parallel component in fields varying from 20,000 to 40,000 gauss seem to indicate, however, that the effect is not purely quadratic as would be expected; for the smaller field strengths the shift (to the red always) is proportional to the square of the field, while for larger fields it seems to be more nearly proportional to the first power, indicating that the true character of the relation is probably a combination of the two.

56. Stellar Stark Line He λ4470. J. S. FOSTER AND A. V. DOUGLAS, *McGill University.*—At Victoria we have taken 3-prism spectra of γ Pegasi and three other B stars showing Stark effects. From the contours of the line He λ4471 we have constructed, in each case, the theoretical Stark line λ4470 $(2p'-4f)$ which should accompany it. Struve has observed in many B stars a rather strong line at 4470 which he has identified as $2p-4f$. The calculations show, however,

that the true Stark line should be relatively weak, with an appreciable displacement toward the violet from zero field position. On many of our plates the theoretical $2p-4f$ is identified with a well-defined portion of the heavy complex line which otherwise remains unknown.

57. Isotope Shift in Neon. J. H. BARTLETT, JR. AND J. J. GIBBONS, *University of Illinois.*—The theory of isotopic displacement due to the motion of the nucleus (See Hughes and Eckart, Phys. Rev. **36**, 694 (1930)) has been extended to atoms with any number of electrons, and applied to the transitions $2p^53s-2p^53p$ in neon. With the Hartree method, single electron wave functions have been obtained. The theory gives a shift in singlet states of 0.022 cm^{-1} more than that in triplet states, as against approximately 0.018 cm^{-1} measured by Nagooka and Mishima (Scientific Papers, Tokyo Institute, **13**, 306 (1930)).

58. Redetermination of the Mass Ratio of the Lithium Isotopes from the Band Spectrum. F. A. JENKINS AND ANDREW MCKELLAR, *University of California.*—Using new spectrograms of the $^1\Pi \leftarrow {}^1\Sigma$ bands of Li_2 from the second order of the 21-foot grating, accurate wave-length data have been obtained for the (0,0), (0,1) and (0,2) bands from both the isotopic molecules, Li^7Li^7 and Li^6Li^7. From these data, the vibrational and rotational constants for the $^1\Sigma$ state have been computed by least squares, and values of the mass-coefficient ρ ($=(\mu/\mu^i)^{\frac{1}{2}}$) obtained which are considerably more accurate than those previously found from the $^1\Pi$ state. The best value of ρ, obtained as the quotient $\omega_e{}^i/\omega_e$ is 1.04141 ± 0.00008. This corresponds to a mass ratio $Li^7/Li^6 = 2\rho^2-1 = 1.1690 \pm 0.0003$. The mass-spectrograph data of Costa give a ratio of 1.1663, with an estimated limit of error not exceeding 0.0007. Our new result is still higher than the value 1.1678 ± 0.0008 obtained from the $^1\Pi$ state. Small corrections, due to possible higher terms in the vibrational energy, modification of the formulae in quantum mechanics, etc., have been examined, and their effects shown to be negligible. From the ratio $B_e''{}^i/B_e'' = \rho^2$, we find $\rho = 1.0422 \pm 0.0007$, in satisfactory agreement with the results from the vibrational constants. Experiments on the disintegration of Li^7 by protons give accurately the mass of Li^7 as 7.015, and using this we find the mass of Li^6 to be 6.001.

59. Nuclear Moment of Na, and Polarization of Resonance Radiation. N. P. HEYDENBURG AND A. ELLETT, *State University of Iowa.*—The zero field polarization of Na D resonance radiation, 16.5 percent agrees with that calculated for a nuclear moment of 1 (16.6 percent), whereas Rabi (Stern, Gerlach) and Urey (Bands) find $I = 3/2$ for which the polarization is 15.4 percent. The zero field polarization of the $\lambda 3303$ doublet is found to be 19.2 percent (Heydenburg) too high for either $I = 1$ or $3/2$. The value of 15.4 percent for $I = 3/2$ is computed on the assumption of uniform intensity distribution in the source and perfectly sharp stationary states. Correcting for intensity distribution raises the polarization (0.2) to 0.6 percent. Breit (private communication) has worked out the effect of finite breadth of stationary states. By calculating intensities in the Paschen-Back effect of hyperfine multiplets for $I = 3/2$ and fitting observations (Larrick, D lines; Heydenburg, $\lambda 3303$) we find $A(4^2P_{3/2}) = 1.93 \times 10^{-4}$ cm^{-1}, $A(3^2P_{3/2}) = 7.7 \times 10^{-4}$ cm^{-1}. With $\tau(4^2P_{3/2}) = 3.7 \times 10^{-8}$; $(3^2P_{3/2}) = 1.6 \times 10^{-8}$, the corrections for finite breadth of states and distribution in source give $P(D_1+D_2) = 16.5$ percent, $P(\lambda 3303) = 18.8$ percent. Experimentally the ratio $A(3^2P_{3/2})/A(4^2P_{3/2})$ is found to be 4 while Goudsmit's theoretical equations give 3.3 for this ratio, and 0.035 cm^{-1} as the separation in $3^2S_{\frac{1}{2}}$ when calculated from the A values of $^2P_{3/2}$, compared with Schüler's 0.06 cm^{-1}. τ values were calculated from Prokofjew's theoretical f values.

60. Rotational Structure of the Raman Band (0000) $\rightarrow$(020$\pm$2) in Linear Symmetrical Molecules YX_2. J. RUD NIELSEN, *Institute of Theoretical Physics, University of Copenhagen.*—A. Langseth and the writer (Zeits. f. physik. Chemie **B19**, 427 (1932)) observed six very faint lines in the Raman spectrum of CO_2 and interpreted them tentatively as maxima of rotational branches. The lines 1325 and 1344 cm^{-1} were ascribed to transitions from the normal state to the level $V_1 = 0$, $V_2 = 2$, $V_3 = 0$, $l = \pm 2$. Because of the apparent absence of a Q-branch, doubt was expressed as to the correctness of this interpretation. In order to clear up this point, the intensities of the individual rotational lines associated with the transition (0000) $\rightarrow$(020$\pm$2) have been calculated. The calculation, which is based upon Placzek's polarizability theory, follows a method similar to that employed by Rademacher and Reiche (Zeits. f. Physik **41**, 453 (1927)) and leads to results agreeing with the more general formulas recently obtained by Placzek and Teller (Zeits. f. Physik **81**, 209 (1933)) by a formally different method. It turns out that a Q-branch should be present. Hence, the doubt as to the interpretation of the lines has not been removed, and further experimental evidence is desirable.

61. Raman Spectra of Some Linear Triatomic Molecules. A. LANGSETH AND J. RUD NIELSEN, *University of Copenhagen.*—A detailed study has been made of the Raman spectra of N_2O, CO_2, liquid CS_2, and the ions SCN^- and N_3^- in aqueous solution. All spectra have been photographed with high dispersion, and, with the help of a spectrograph of lower dispersion, the depolarisations of the main lines have been determined for all molecules except N_2O. For CO_2 and CS_2 the relative intensities were also measured. The results obtained, which are discussed in the light of the theories of Fermi, Dennison and Placzek, support the conclusion that these molecules are of linear structure.

62. A New Monochromatic Filter. W. H. AUGHEY AND W. D. LANSING, *Experimental Station, E. I. duPont de Nemours and Company.*—In the course of ultra-centrifugal investigations, a need was felt for monochromatic blue (4358A) radiation from a Hg arc. No available dry filter was found to transmit the blue without contamination from the violet (4047A) line. It was discovered that an alkaline solution of β-methyl esculetin (Vliet, Organic Syntheses, **IV**, 45–6 (1925)) would transmit the blue line and absorb the violet completely. Dry filters were made by bathing

fixed and washed photographic plates in a 0.2 percent water solution of the dye with sufficient sodium hydroxide to neutralize one of the hydroxyls in the dye. After drying, completed filters were made by cementing two plates with the gelatine sides together. With ordinary photographic plates, the only radiation from a quartz mercury arc transmitted in sufficient intensity to affect the plate is the 4358A line. This filter, it must be pointed out, is only a photographic monochromat, and cannot be used for visual work.

MONDAY AFTERNOON AT 2:00 O'CLOCK

Eckhart Hall, Room 202

63. X-ray Investigations at High Pressures. WILLI M. COHN, *Berkeley, California.*—X-ray investigations have been carried out with a Bridgman bomb. The substance to be investigated is inserted into the bomb, and the pressure applied. A monochromatic x-ray beam passes through the following parts in the bomb: slit, beryllium window, slit, sample, window of amorphous material (Bakelite, glass). The film is arranged outside of the bomb. Hydrostatic pressures have been obtained up to 3000 atmospheres so far. Some results of the experiments are discussed showing changes of modifications taking place in the crystals investigated.

64. The Crystal Lattice of Ammonium Persulphate, $(NH_4)_2S_2O_8$, and the Structure of the Persulphate Group. R. C. L. MOONEY AND W. H. ZACHARIASEN, *University of Chicago.*—The crystal lattice of the isomorphous ammonium and caesium persulphates was determined accurately and uniquely in order to obtain exact data on the structure of the persulphate group. The symmetry is monoclinic and the space group is $P2_1/n$ (C^5_{2h}). The unit cell contains four molecules. All atoms are lying in general positions, so that the lattice is characterized by 18 degrees of freedom. The cell size and parameter values for the ammonium compound are: $a=7.80$A $b=7.98$A $c=6.12$A $\beta=95°9'$. The per-

	$2\pi x$	$2\pi y$	$2\pi z$		$2\pi x$	$2\pi y$	$2\pi z$
NH_4	52°	45°	90°	O_{II}	10°	75°	250°
S	49°	126°	260°	O_{III}	75°	145°	340°
O_I	15°	180°	215°	O_{IV}	105°	120°	210°

sulphate group may be pictured as two SO_4 groups linked together by a bond across a center of symmetry between two oxygen atoms. Each sulphur atom is tetrahedrally surrounded by four oxygen atoms at a distance of 1.50A. The distance between two oxygen atoms connected by the valence bond is 1.31A. The angle between the two bonds of these oxygen atoms is 128°. The structure of the group may be interpreted in terms of electron pair bonds by writing the formula as $(O_3^{-1}\,S^{+2}\,O\,O\,S^{+2}\,O_3^{-1})^{-2}$. Ammonium is surrounded by 12 oxygen atoms at an average distance of 3.15A. The atomic arrangement explains the observed birefringence.

65. The Crystal Structure of Boric Acid. W. H. ZACHARIASEN, *University of Chicago.*—The crystal lattice of boric acid, H_3BO_3, was determined in order to get information about the hydrogen bond. Boric acid crystals are triclinic holohedral with the following dimensions of the unit cell: $a=7.04$A $b=7.04$A $c=6.56$A $\alpha=92°30'$ $\beta=101°10'$ $\gamma=120°$. This cell contains four molecules and there are thus 42 degrees of freedom in the structure. The positions of boron and oxygen atoms were fixed by intensity considerations and may be described as follows:

	$2\pi x$	$2\pi y$	$2\pi z$		$2\pi x$	$2\pi y$	$2\pi z$
B_I	235°	155°	90°	O_{III}	275°	235°	90°
B_{II}	115°	275°	90°	O_{IV}	75°	195°	90°
O_I	155°	115°	90°	O_V	75°	315°	90°
O_{II}	275°	115°	90°	O_{VI}	195°	315°	90°

The hydrogen positions were determined by considerations of interatomic distances. Conveniently the structure may be described as a pile of identical and strictly twodimensional lattices. The vertical distance between successive layers is 3.18A, so that the forces linking the layers together are extremely weak. The atomic arrangement within each layer is of hexagonal symmetry. The building blocks of the twodimensional lattice are triangular BO_3-groups (B—O =1.35A) and collinear O—H—O groups (O—O =2.71A). Each oxygen atom is linked to one boron and two hydrogen atoms. The layers are piled together in such a manner that the oxygen atoms of one layer are lying almost exactly above or below boron and hydrogen atoms of the two neighboring layers. The atomic arrangement accounts for the properties of the crystals.

66. The Crystal Structure of Sodium Thio-antimonate. CHING-YEUNG HUI, *Cornell University.*—Sodium thioantimonate ($Na_3SbS_4 \cdot 9H_2O$), an optically active cubic crystal, was investigated by x-rays. Laue, oscillation and powder photographs were made. There are four molecules to the unit cell, the length of which is 11.835A. The density calculated from the x-ray data is 1.927 as compared with 1.864 given by C. Soret as the best value (Archiv. de Sci. Physiques et Naturelles **16**, 468 (1886)). The space group is $P2_12$ (T^4). There are four optically active cubic crystals known to the author. Each of these has now been shown to belong to $P2_12$.

67. Crystal Structure of Potassium Uranyl Acetate. I. FANKUCHEN, *Cornell University.*—Potassium uranyl acetate has been reported as tetragonal, axial ratio = 1.2831. A study has been made with powder, rotation, oscillation

and Laue methods. These indicate that it is dimorphous, both forms being tetragonal. For one, $a=14.38$, $c=25.80$. This corresponds to an axial ratio of 1.27, checking the reported value. For the other, $a=13.99$, $c=27.70$. Its axial ratio, 1.40, lies in the range of values of the axial ratios of the remainder of the uranyl acetates reported as isomorphous with the potassium uranyl acetate. Both unit cells have approximately the same volume and contain 16 molecules. Both are body centered. The space group is probably $I4_12$ (D_4^{10}). In both forms the uranium atoms are approximately in a face centered lattice of 1/4 the height of the actual unit cell. This is more nearly the case in the second form.

68. X-Rays Produced by Fast Mercury Ions. WESLEY M. COATES AND ERNEST O. LAWRENCE, *University of California.*—A study has been made of the production of x-rays by mercury ions having energies up to 2.4×10^6 electron-volts. The ions were obtained by the method of Sloan and Lawrence (Phys. Rev. **38**, 2021 (1931)). The following targets were used: lithium, boron, carbon, oxygen, aluminum, sulfur, nickel, copper, molybdenum, silver, tin and lead. The radiation first becomes measurable when the ions have energies of about one million electron-volts and the intensity increases rapidly as the energy of the ions increases. For all of the elements lighter than copper the wave-length of the radiation is characteristic of the target. The elements heavier than copper give the mercury M radiation in increasing abundance as the atomic number increases. The intensity of the radiation excited in molybdenum by the mercury ions is about ten times as great as that excited in the same target by 3800 volt-electrons. The efficiency of the process is such that at least one out of every 2000 mercury ions having an energy of 2.4×10^6 electron-volts succeeds in producing a 2400 volt quantum from a silver target.

69. Scattering of X-Rays from Powdered Crystals at Low Temperatures. FORD PENNELL AND G. E. M. JAUNCEY, *Washington University, St. Louis, Missouri.*—We have recently shown (Phys. Rev. **43**, 505 (1933)) that Jauncey's theory of the diffuse scattering from crystals together with the theory of the intensity of the Debye-Scherrer circles gives the intensity of the x-rays scattered by a powdered crystal over a wide range of values of $(\sin\frac{1}{2}\phi)/\lambda$ into an ionization chamber window. We have now determined the ratio of the intensity of x-rays scattered from the powdered crystal at 103°K to that from the crystal at 295°K for each of several scattering angles between 12° and 36°. For KCl the ratios varied from 0.965 to 0.995 with a probable error of about 0.012. For NaF the ratios varied from 0.960 to 1.015 with a probable error of about 0.010. The ratios are thus nearly unity but show a tendency, more marked in the case of KCl, to be less than unity by the order of one percent. This may indicate a slight decrease of the true atom form factor at low temperatures, a possibility suggested by Jauncey (Phys. Rev. **42**, 453 (1932)).

70. Sensitiveness of Photographic Films to X-Rays at Low Temperatures. G. E. M. JAUNCEY AND H. W. RICHARDSON, *Washington University, St. Louis, Missouri.*—Dewar found that the sensitiveness of a photographic film to light is considerably reduced when the film is at liquid air temperature. Likewise it is known that the sensitiveness to x-rays is reduced at this temperature. We have made a quantitative study of the sensitiveness to x-rays of different parts of the same film which were at different temperatures. The amount of blackening of a film was determined by means of a microphotometer. The exposure times necessary to produce equal blackening at temperatures of 103°, 203° and 293°K, respectively, were determined. From these the rates of blackening for a given intensity of x-rays were found to be proportional to 0.32, 0.49 and 1.00 at the respective temperatures. On plotting against temperature and drawing a monotonic curve, it seems that the rate at 0°K is 0.17 or about one-sixth of the rate of blackening at room temperature. The x-ray tube was operated at 55 kv peak and the rays passed through 1.065 cm of aluminum. The effective wave-length as measured by absorption was 0.33A.

71. The Magnitudes of the L Absorption Discontinuities of Thallium. C. G. PATTEN, *University of California.* (*Introduced by R. B. Brode.*)—Uniform evaporated films of thallium were used in obtaining values for the magnitudes of the L absorption discontinuities and the variations of the absorption coefficients with wave-lengths. The thallium was of such a thickness as to absorb over 50 percent of the radiation at the maximum values. The thallium film was coated with a very thin film of aluminum to prevent oxidation. The ionization currents were measured with a (FP_{54} Pliotron) vacuum tube amplifier and an accuracy of one percent is claimed. By considering the scattering as negligible the magnitudes of the discontinuities are

$$\delta_{L_1}=1.149,\quad \delta_{L_{II}}=1.409,\quad \delta_{L_{III}}=2.529,\quad \delta_L=4.093.$$

Values of c, the exponent of λ in the equation $\mu=A\lambda^c$, have been obtained. The results are in good agreement with values obtained for gold by Uber and Patten, Phys. Rev. **42**, 229 (1932).

72. The Laws of Absorption for Soft X-Rays. ELMER DERSHEM, *University of Chicago.*—The absorption of the unresolved $L\alpha_{12}$ lines of copper ($\lambda=13.37$A) and iron ($\lambda=17.67$A) in nitrogen, oxygen and carbon dioxide has been investigated by a photographic method previously described by Dershem and Schein, Phys. Rev. **37**, 1238 (1931). Improvements in apparatus and technique have made it possible to measure the x-ray absorption coefficients of a gas in this wave-length region with a probable error for a single observation not greater than 1.5 percent. The results so far obtained show that for wave-lengths shorter than that of the K limit the absorption coefficients vary approximately as the 2.35 power of the wave-length and the 4.36 power of the atomic number of the absorber. For hard x-rays these values are known to be very closely 3 and 4, respectively. The present results are in good agreement with those of other investigators who have used moderately soft x-rays and found that the exponent of λ decreases steadily with increase in λ while the exponent of Z increases slightly with increase of wave-length.

73. Wave-Lengths of Certain *M* Series Lines by the Ruled Grating. E. G. PURDOM AND J. M. CORK, *University of Michigan.*—By using the experimental procedure described by one of us (Phys. Rev. **35**, 1456 (1930)), (Phys. Rev. **42**, 743 (1932)), measurements have been extended to include the *M* series emission spectra for the heavy elements. This method makes use of multiple positive orders and allows the correct determination of the wave-lengths even should uncertainties exist in the position of the direct or reflected beam or in the angle of incidence. With the exception of rhenium (75), at least five good plates have been obtained and the wave-lengths determined for the elements from hafnium (72) through bismuth (83), thorium (90) and uranium (92). The wave-lengths are found to be consistently greater than the corresponding results obtained by means of the crystal method. Moseley diagrams for the various lines are smooth curves.

74. Experimental Study of the Rocking Curves of the Mn $K\alpha$ Lines from Pure Mn and from Several Mn Alloys. LYMAN G. PARRATT, *University of Chicago.*—With a double-crystal vacuum spectrometer rocking curves of the Mn $K\alpha$ lines from pure Mn and from several alloy targets have been recorded. The widths at half maximum intensity vary with the combination of elements and with their relative concentrations in the target. Targets of Mn–Ni show an approximately linear increase in the width of $K\alpha_1$ with relative increase of nickel, reaching at 50–50 molecular concentration a maximum width 23.3 percent greater than the width from pure Mn, then an approximately linear decrease with the same slope as before. The eutectoid mixture of Mn–Cu also shows increased width; an alloy of Mn–Fe (50–50) yields little or no increase; Mn–Cr (50–50) gives a decrease of some 5 percent. A layer of oxide on the surface of the pure Mn target increases the width as much as 18.7 percent. Changes in the width of α_2 follow closely those of α_1. All the rocking curves are asymmetrical and their shapes vary with the type of target used. The relative intensity of α_1 to α_2 (if taken as the ratio of areas under the resolved or component rocking curves) remains 2 to 1 irrespective of the composition of the target.

SUPPLEMENTARY PROGRAM

When two or more papers are offered by the same member one only of these will be assigned a place on the regular program while the others will be placed in a supplementary program to be called if time permits.

Papers received after the program has been printed will be placed in the supplementary program.

The papers in the supplementary program may be called for at the end of the regular sessions in Eckhart Hall, Room 202.

Paper No. 76 will be read by title

75. A Method to Supplement Dimensional Analysis. ARTHUR E. RUARK, *University of Pittsburgh.*—Attempts to apply dimensional analysis often yield misleading results because of failure to include all the independent variables, and dimensional constants. The technique of dimensional analysis contains no prescription for discovering and eliminating such errors. Often, to avoid these difficulties, dimensional analysis may be replaced by another procedure. This consists in writing down the differential equations and boundary conditions of the problem, or of some problem of the same type characterized by simpler geometrical and kinematic conditions. The variables can always be replaced by dimensionless ones. The dimensionless variables and dimensional constants which appear in these equations are identical with those occurring in the final integrated form of our physical equations. The dependent variables can be written out as power (or Fourier) series involving the independent ones, and study of their form is often helpful. Physical dimensions, natural periods, etc., cannot well be overlooked. Defects in our knowledge, preventing complete formulation of the problem, are brought out clearly by this procedure. When one is unable to write out approximate differential equations and boundary conditions, it is hard to see how a dimensional analysis could succeed, except by chance.

76. A Photographic Recording Photoelectric Densitometer. L. T. DEVORE, *The Pennsylvania State College.*—Difficulties encountered by previous workers in designing a direct reading photoelectric densitometer have been largely overcome in the design of this instrument. The cell employed is a P. J. 23 gas-filled, central anode tube operated at a low anode potential. A d.c. amplifier has been developed and methods evolved for calibrating this amplifier and keeping its characteristics constant under operating conditions. A simple photographic recorder has been developed. The instrument is capable of duplicating results with great precision.